THE MANAGEMENT OF NATECH EVENTS IN SEVESO SITES FOR THE CASE OF FLOOD RISKS

Romualdo Marrazzo
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ISPRA - Istituto Superiore per la Protezione e la Ricerca Ambientale, Roma, ITALY
romualdo.marrazzo@isprambiente.it

Abstract

The Seveso III Directive 2012/18/EU imposes an obligation for the site operator to identify the major risks of the establishment, taking also into account technological accidents such as fires, explosions, and toxic releases that can occur following natural disasters (so-called NaTech risks). Floods, which are amplified by climate change, are among the most widespread natural dangers in European countries. The Safety Management System for the Prevention of Major Accidents in Seveso Sites is important in ensuring the correct implementation of the prevention and protection measures against major accidents originating from these events, with specific procedures for extreme weather conditions. Starting from the main outcomes of the analysis of industrial accidents, where floods have been identified as a significant and triggering cause, a specific focus is then presented on the main types of plants, infrastructures, and industrial equipment vulnerable to extreme weather conditions. These lessons learned are also useful examples of how organizations could manage these problems, through specific procedures, good practices, and methods used to assess the industry's response to NaTech issues. A practical case of application of safety evaluations has therefore been reported for a type of industrial plant that is particularly relevant on the Italian territory, namely the underground storage of natural gas. The risks of floods are particularly relevant because of the extension of these plants over large areas, which means that parts of them can pass through areas subject to flooding. Finally, the article describes an in-depth analysis carried out on the NATECH risk of flooding for industrial plants, starting from the Italian technical regulation, with details to be considered in the risk assessment for the identification of the critical elements for safety, as well as the main prevention and protection measures for equipment.

Keywords: Seveso, SMS, procedures, NATECH, events, flood

I. Introduction

The Seveso III Directive 2012/18/EU, implemented in Italy by the D.Lgs. 105/2015 [1], imposes an obligation for the site operator, in identifying the hazards and assessing the major risks of the establishment, to take the NATECH risks into account, paying attention to the entire spectrum of natural hazards that may affect the site. With the term NaTech, the international literature identifies technological accidents, such as fires, explosions, and toxic releases that can occur inside industrial establishments and along distribution networks and pipelines following natural disasters.

The evaluation of the effects of natural events on Major Accident Hazard establishments requires a systemic and multidisciplinary approach concerning the complexity of the contexts to be analyzed both from the plant and structural point of view. The methodological approach for assessing the NATECH risks of Seveso sites must be based on meeting the objectives underlying the regulatory text, which consist of preventing major accidents connected to the presence of dangerous substances and limiting their consequences for human health and the environment.

It is therefore considered necessary, with this paper, to provide support for the evaluation of the implementation of the Safety Management System for the Prevention of Major Accidents

(SMS-PMA) during the control activities on Seveso establishments, with specific attention to the checks to be carried out during inspections regarding the NATECH risks, according to the D.Lgs. 105/2015.

II. Methods

The incidental data extracted from the e-MARS database of the European Commission show that from 1985 to today in the EU countries, there has been an average NATECH accident per year, while about 7000 accidents that occurred in industrial sites, collected in the Bank UK-HSE MHIDAS data [2], 3% of accidents are classified as NATECH having been induced by natural events such as earthquakes (8%), floods (16%), landslides (7%), strong winds (13 %) and lightning (56%). Fig. 1 is shown below, which represents the number of accidents occurring as a function of extreme natural events [3].

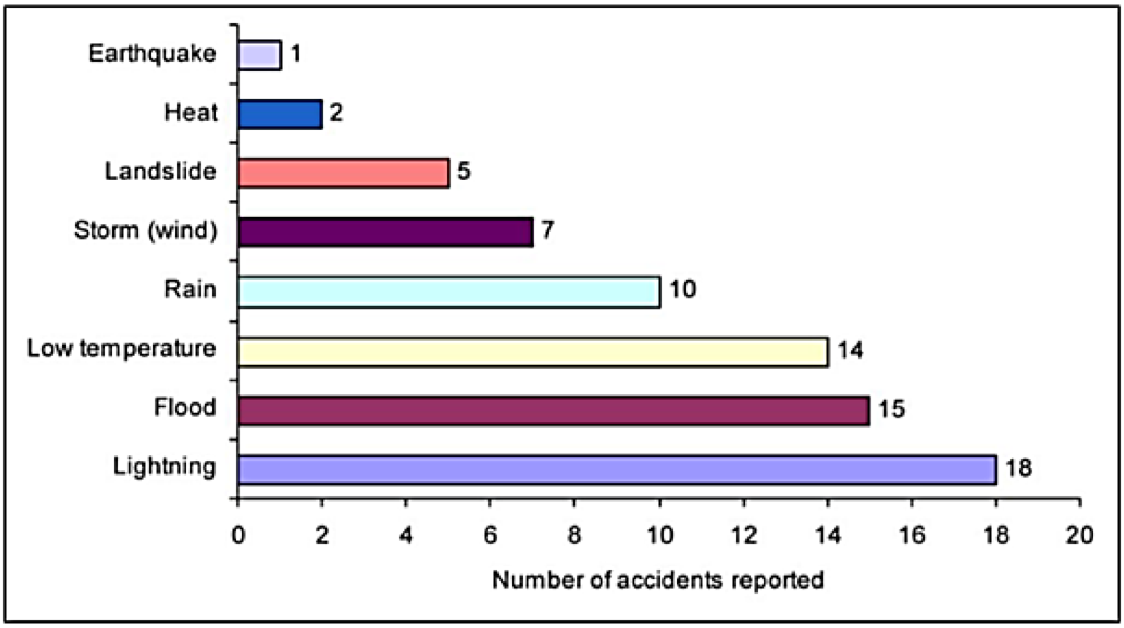

Figure 1: *Number of accidents occurring as a function of extreme natural events*

In Table 1 below it is possible to summarize the main types of plants, infrastructures, and industrial equipment vulnerable to natural hazards in the event of adverse weather conditions.

Table 1: *Equipment and plants vulnerable to natural hazards*

Industrial equipment and plants	Natural hazards for adverse conditions
Gas, fuel oil, and coal thermoelectric power plants	Floods
Pipelines for the transmission and distribution of gas, oil pipelines	Floods (Landslides)
LPG depots	Floods
Mineral oils depots	Floods, lightning, strong winds, storms
Refineries and chemical and petrochemical plants:	
Process columns	Strong winds, storms
Above ground tanks	Strong winds, storms, floods, lightning
Mounded tanks	Floods
Pipelines (also underground)	Floods
Motors, pumps, compressors	Floods

Control room and instrumentation	Floods, lightning
Warehouses of packed products	Floods
Service utilities commonly found in industrial plants whose failure can lead to hazardous situations: boilers; refrigeration systems; cooling towers; power supply; water treatment; torch systems	Strong winds, storms, floods, lightning, changes in water availability, increases in water temperatures, and decreases in availability of cooling water
Toxic products depots	Floods
Warehouses of phytosanitary products	Floods
Coastal depots, plants, and terminals	Sea storms, sea level rise

I. Floods

As indicated in Table 1, floods (which in turn may or may not be a direct consequence of the occurrence of earthquakes), with consequent landslides (depending on the terrain) are the most widespread natural danger in our country, and many productive activities in all sectors are vulnerable in the event of adverse weather conditions.

The danger of floods can never be eliminated and therefore every manager of a Seveso establishment must prepare in advance to limit the impact that a flood could have on its activities, through dedicated planning that considers that an event of this type could trigger or make a major accident more serious, directly or indirectly.

He must therefore provide, through the adaptation of its SMS-PMA (Safety Management System for the Prevention of Major Accidents), the necessary measures to prevent or limit the consequences for human health and the environment.

Directive 2007/60/EC relating to the assessment and management of flood risks (Floods Directive - FD) [4], provides the elements for the assessment and management of this type of risk which in Italy is implemented with D.Lgs. 49/2010 [5].

II. Industrial accidents following floods

Following continuous torrential rains which lasted several days, the plants of a refinery located in the port area flooded (Mohammedia refinery in Morocco in 2002). Production was stopped due to the water level. A violent fire followed, as well as several explosions of tanks, electrical equipment (transformers), and pipes. Four hours later, fires persisted in the gas and crude oil sectors of the refinery. The fire was extinguished after 20 hours. Two people died and four were injured. Extensive material damage resulting from the accident led to the closure of the refinery and the suspension of all activities.

The sequence of fires was caused by the flood that moved the exhausted oil, displacing it from the sewer system. The waste oil that floated on the surface then encountered the hot parts of the systems, causing several fires and explosions in the pipes and electrical transformers. From the above it is fundamental:

- Implement effective procedures to prevent the rapid distribution of flammable liquids by alluvial waters;
- Good maintenance practice is to make sure the drains are clean so that they don't block the water drain.

The site manager, to mitigate the impact of a flood, must undertake a series of improvement actions to make the perimeter of the plant, buildings, or specific areas within buildings or equipment containing hazardous substances (in quantities and conditions such as to cause a major accident), inaccessible to water.

These actions include the following types of protection (or combinations thereof): Construction of defense works (structural measures, such as embankments, drainages, stabilization, roofing); Closure of openings and water entry points; Waterproofing of walls; Seal the penetrations in the walls; Installation of pumps for the collection and removal of water (dewatering pumps); Installation of non-return valves; Ensure a control plan periodically and be carried out afterward a flood and before an expected flood.

The site manager should also locate fire pumps, sprinklers, suppression systems, and other fire suppression systems, with associated electrical equipment, outside of flood hazard areas or above the maximum achievable water level.

If there is critical equipment for process safety, production, or operations that are located at a lower level than the maximum achievable by the water, the site manager must ensure they are flood-proof (if their functionality is required during the flood for safety reasons or to ensure continuity of production). In the case of electrical equipment, it must be designed to work even if continuously immersed and have an electrical classification IP X8 (protected by permanent immersion in water - submersible to 3 m depth in continuous immersion and in any case for more than one hour, resistant to a pressure of at least 10 bar exerted in all directions).

III. Results

I. The case of underground natural gas storage as strategic assets

The underground natural gas storage are located in depleted underground deposits of the same mineral. The storage of natural gas is an industrial process that consists of injecting gas into an underground rock system, to guarantee its accumulation and subsequently supply it in a second phase, to face a market demand or to face situations of lack/reduction of supply. Storage therefore play a strategic function for national energy reserves, being considered strategic assets for the Italian industry.

In summary, the process in which natural gas intervenes is represented by two phases that alternate during a year of operation:

- The phase of injection of gas through wells, in the spring-summer period, which consists of storing the natural gas coming from the network transport in the field through the wells after compression
- The gas supply phase, in the autumn/winter period, during which the gas is supplied, dehydrated, treated, and redelivered to the transport network.

The main areas involved in the process concern: reservoirs, wells and cluster areas, compression plants, treatment plants, and pipelines. Twelve underground natural gas storage sites are in Italy, operating in five different regions in the central north of the country [6].

To provide technical support for the assessment of the safety reports of underground natural gas storage establishments, pursuing a uniform assessment throughout the national territory, also given the peculiarity of these establishments, the Guidelines "Underground storage of natural gas - Guidelines for the evaluation of Safety Reports", issued in October 2018 [7] were drawn up by a Working Group set up by the Italian National Authorities involved in industrial control activities on Seveso establishments. The Guidelines deal in depth with the issue of risk analysis, and also include NaTech risks of floods, based on a national overview of the Safety Reports presented by the site managers of the underground natural gas storage.

Finally, the Internal and External Emergency Planning for NaTech events must necessarily consider that such events may involve a plurality of contemporary emergencies, the interruption of electrical and telephone lines and communication routes. It is therefore necessary to implement and deepen these aspects in emergency planning, taking care of the training of both plant personnel and external intervention structures.

II. NaTech Risk Assessment in Underground Natural Gas Safety Reports

A complete NaTech risk analysis consists of the following steps:

- Preliminary analysis, carried out through territorial contextualization, historical analysis of natural events, and assessment of the hazards of each NaTech event considered for the site
- Identification of equipment exposed to risk

- Identification of prevention and mitigation measures, possible estimate of occurrence frequencies and areas of damage, relative integration of the scenarios in the Safety Report

Based on the Safety Reports examined, the site Managers completed the first of the phases indicated; in some specific situations, the second phase and part of the third phase have also been completed, as requested by the Competent Authorities, identifying the prevention and mitigation measures. Based on the safety reports examined, the technical assessment of the scenarios still must be faced. Given the relevance of the NaTech risk of floods, because of the extension of these plants over large areas, which means that parts of them can pass through areas subject to flooding, particular attention has been paid to the hydrogeological risks.

III. The evaluation of the hydrogeological risks

Natural gas storage, compared to other types of establishments, have the peculiarity of insisting on vast territories belonging to municipalities, provinces, and sometimes even different regions, as they consist of compression and treatment plants, pipeline connections, well areas, cluster areas, and related equipment.

It can be stated that it is not uncommon for a part of the plants to be in areas subject to risk of hydrogeological instability and flooding, as identified by the sector planning tools, prepared by the competent district basin authorities for the area. In some cases, although the risk maps didn't cover specific areas, the plants were affected by instability and flooding phenomena, based on the data deriving from the analysis of the historical experience gained and from the consultation of specific databases.

In the implementation of the Seveso III Directive, attention was paid to also carrying out the analysis of technological risk induced by instability and flooding. To date, also thanks to the indications contained in the Guidelines, the Companies have produced an in-depth analysis of the risk of damage to equipment and piping because of instability or flooding. The following paragraphs indicate the methodologies that have been applied to assess these risks, their limits, and the margins for improvement.

IV. Failure risk analysis

In situations in which the plants and pipes are in areas subject to hydrogeological instability, specific studies were requested from the Site Manager, also following the indications of the Guidelines, for the evaluation of risk and planning intervention actions to mitigate it.

The studies produced have addressed the problem in the way described below. The available bibliographic studies on the geological, geomorphological, and hydrogeological structure of the study area were first described. Investigations were carried out on the seismicity of the territory on a local scale. The pipeline routes and plant areas were reported on the thematic maps drawn up by the competent Basin Authorities. The study was therefore carried out through careful surveys in the field, extended to all plant areas and along the connecting pipelines, with particular attention to the areas affected by criticalities even if not registered by the territorial planning tools. The predisposing factors for the establishment of conditions of instability (morphological configuration, geo-lithological nature of the sediments present) and the determining factors (periods of intense precipitation) were therefore identified. The surveys carried out were promptly reported in synoptic cards, accompanied by extensive photographic documentation, and then reported on detailed thematic maps.

The main problems highlighted were:

- Areas subject to erosion. For the areas subject to erosion, areas with surface erosion on slopes denuded by vegetation cover and areas subject to river erosion, in turn, distinguished between bottom or bank erosion, were distinguished
- Areas subject to slope instability. The areas with problems relating to the stability of the slopes have been divided according to their degree of danger to the integrity of the pipelines, distinguishing the following types: Active landslide, Quiescent landslide, stabilized landslide, surface landslide, widespread instability

The analysis and survey activity highlighted various areas with articulated morphologies, which indicate a certain propensity for the slopes to fall apart. Some of these situations were considered "to be monitored over time", to detect any changes.

In the areas of fluvial relevance, problems have been found in progress, following the erosive actions carried out by the waterways. For these problems, the Company has prepared and implemented structural interventions consisting of moving the pipelines or restoring the bank. For each area, the Company has defined the interventions and checks to be carried out, considering the situation observed, to safeguard the integrity of the conduct and to follow any developments in the failures.

The mentioned periodic monitoring activities have been included in the Safety Management System and are subject to verification during the inspections provided for the D.Lgs. 105/2015. Periodically, following the monitoring activities, the Company communicates to the Competent Authorities the planning of improvement, consolidation, and restoration interventions, with all the necessary authorizations from the bodies in charge. The Site Manager has also identified prevention/mitigation measures, consisting in the interception of equipment and pipes in the areas at risk, in the event of a weather alert.

The methodology chosen certainly constitutes a starting point for the analysis and management of the risk deriving from failures.

In situations that need more attention, a possible action for improvement can be identified in associating visual monitoring with instrumental measurements aimed at quantifying any landslides. In fact, in this way, it will be possible to identify attention limits, so as to guarantee the persistence of security conditions. Further actions can be carried out, such as intensifying monitoring and carrying out stability checks of the slopes, in case of more severe conditions.

If the results of the further actions indicated above shows situations of increased risk above "acceptable" values, without prejudice to any mandatory provisions implementing in the planning tools, it will be necessary to plan structural interventions aimed at guaranteeing the stability of the plants. Typical examples are:

- Construction of consolidation and stabilization works for risk mitigation, after a hydrogeological compatibility study and approval by the competent Authorities
- Delocalization of pipes and systems

A further aspect of improvement is the in-depth study of the accident scenarios resulting from instability, by evaluating the probability of loss of containment, subsequent ignition of the released gas and calculation of the areas of damage.

V. Hydraulic risk analysis: the consideration of flooding

For plants and structures located in areas at risk of flooding, the site Managers were asked to carry out a specific risk assessment. The study produced was of a multidisciplinary type and started from field surveys in all plant areas and along the connection network falling within areas even if not recorded by the territorial planning tools. In particular, the following activities were preliminarily carried out:

- Survey for the topographical definition of the study area.
- Geo-gnostic and geophysical investigations campaigns aimed at the stratigraphic, hydrogeological and seismic reconstruction of the study area. These studies make it possible to identify the characteristics of the subsoil and the seasonal groundwater levels.
- Vegetational surveys and development of the relative cartography.
- Bibliographic studies of the geological, geomorphological and hydrogeological structure of the study area, supplemented by hydro-morphological survey activities in the field to apply the IDRAIM (Italian acronym for "Hydromorphological evaluation system, analysis and monitoring of watercourses") methodology [8]. This methodology is aimed at understanding the aspects of fluvial dynamics of the watercourses and at the classification of areas most dangerous due to erosion by the watercourses, providing an overall picture of the hydro-geomorphological evolution processes.

- Detailed hydrological-hydraulic studies for the hydrographic areas. These studies make it possible to analyze the flooding problem in correspondence with the plant areas, carrying out a detailed hydraulic study to determine the water tie rods with a return period of 200 years.
- Evaluation of erosive phenomena at the bottom of the riverbed, in correspondence with river areas where the crossing of the watercourse by operational methane pipelines is detected.

The mentioned activities allowed a complete view of any hydraulic criticalities that could affect the surface systems. Once the plants located in the areas at risk of flooding have been identified, the study analyzed the as-built documentation relating to the plant areas concerned, studying the characteristics of the foundations, the equipment present and the ground, and specifically: dimensions of the foundations; depth of the laying surface; characteristics of the material constituting the foundations: weight of equipment; diameter and thickness of the pipes; depth of burial; characteristics of the pipe’s material; weight of the pipes; soil characteristics.

This detailed analysis, aimed at acquiring all the necessary information relating to the Cluster areas, well areas, and connections, proved to be functional to the verification of the hydrostatic thrusts for the equipment and pipelines.

The risk analysis was completed through geotechnical, load bearing, and lifting capacity checks, for the foundations of the equipment involved and for the sections of pipelines that are potentially floodable or with the presence of seasonal groundwater above the pipeline. A bearing capacity analysis of the foundations was also performed as required by the Technical Standards for Construction. If the checks relating to the buoyancy thrusts and the analysis of the bearing capacity in the event of flooding were not satisfied, without prejudice to any mandatory provisions, it would be necessary to plan structural interventions.

These interventions are aimed at guaranteeing the stability of the structures and the absence of containment losses in the event of flooding, also considering the ongoing climate changes, which make intense and sudden phenomena more and more frequent. They may consist in the relocation of the plants to areas outside those of risk or in interventions to make the structures safe, after a hydraulic compatibility study and approval by the Competent Authorities. Also, for the risk of flooding, as for the seismic and instability risk, the risk analysis carried out up to now by the Site Manager can be completed with the analysis of the accident scenarios resulting from flooding.

IV. Conclusions

The results of the NATECH risks assessment must be considered in the location, design, construction, and operation of the industrial establishment, as well as in the implementation of mitigation measures and emergency planning. The site operator of industrial establishments under the Seveso directive should develop appropriate measures to address natural hazards, to allow the maintenance of control of the plants vital to safety and their safe operation.

In this sense, the Safety Management System for the Prevention of Major Accidents, and the relative integration with the operational management of the establishment, plays an important role in ensuring the correct implementation of the prevention and protection measures against major accidents originating from NaTech events, with specific procedures for extreme weather conditions, such as heavy rainfall, lightning, strong winds and extreme temperatures.

Starting from the main outcomes of the analysis of some industrial accidents, where natural hazards have been identified as a significant and triggering cause, it is possible to focus the main types of plants, infrastructures, and industrial equipment vulnerable to extreme weather conditions. These lessons learned are also useful examples of how organizations could manage these problems, through specific procedures, good practices, and methods used to assess the industry’s response to NaTech issues.

In this framework, the technical evaluation of NaTech risks of underground natural gas storage, as national strategic assets for the national supply of energy sources within the diversification policies, is of particular importance. In addition to the peculiarity of using a natural reservoir for storage, they also extended over large areas, as they consist of multiple plants joined by pipelines (compression and treatment stations, well areas, cluster areas). The characteristics of the activity made it necessary to draw up a Guideline for the assessment of safety reports, focusing attention on natural events or disasters that can induce one or more technological accidents such as fires, explosions, and releases, with particular attention to hydrogeological risk.

The extension of these establishments over large areas means that parts of the system, and particularly the connecting pipes, can cross areas subject to instability and flooding. The analysis conducted in the safety reports has certainly made it possible to focus attention on the problems present; the assessment must be completed with the study of possible accident scenarios deriving from natural risks of floods, to adopt the necessary measures for the prevention, mitigation and management of the emergency.

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